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Physical Characteristics of Krueng Seunagan Watershed and River Storage Capacity Against Peak Discharge

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Abstract – Peak discharge information is indispensable for flood control planning by taking into account the physiographic factors of the watershed. Flood occurs because the capacity of the watershed and river channels is smaller than the flood discharge. One of the causes of rivers' reduced flood flow capacity is vegetation cover and land use that cannot store rainfall. Thus, this paper aims to determine the peak discharge from the watershed's physical characteristics and land-use changes by comparing the river storage capacity in the Krueng Seunagan watershed. The rational method is used to calculate the peak discharge. Some of the data used in this study are the shapefile map provided by Geospatial Information Agency, land use, rainfall, soil types, and Landsat 8 OLI/TIRS digital imagery. Analysis of the physical characteristics of the watershed consists of morphology and morphometry. Land use in the area of the Krueng Seunagan watershed increased the peak discharge during the observation year (2003-2017). Besides the land-use factor, discharge is also influenced by high rainfall intensity and runoff coefficient obtained from land use analysis. In the Krueng Seunagan watershed area, the C value obtained was 0.0505 – 0.0720, indicating that the Krueng Seunagan watershed area was classified as good or harmless. The river flow density of 0.53 belongs to the medium category. The river flow increases and decreases in the flood water level, which is neither too fast nor too slow. The roundness index of the Seunagan watershed of 1.0004 indicates that the basins are widened or circular and, consequently, the rate and volume of surface runoff are fast. Krueng Seunagan watershed runoff coefficient increased by 42.51% and rainfall intensity by 37.05%, while discharge increased by 95.31%. The discharge capacity that the Krueng Seunagan River Basin can accommodate from the measurement results in the downstream watershed is 158.47 m^3/sec. While the peak discharge using the rational method gets a value that varies in each year of observation from (2003-2017). The peak discharge value in 2003 amounted to 183.52 m^3/sec, and the highest in 2017 amounted to 358.44 m^3/sec. This shows that the river holding capacity in the Krueng Seunagan watershed will not accept the amount of peak discharge, and consequently, the flood will always occur.

Keywords: River Storage Capacity, Land Use, Discharge, Krueng Seunagan Watershed.

Introduction

Changes in land use have the most significant effect on the increase in the surface runoff coefficient, which results in the increase of peak discharge as a result of high runoff; this occurs due to the conversion of forest areas to agricultural, residential, or industrial sites (Raharjo et al., 2016). Changes in land cover will significantly change the hydrological response in a watershed. Floods in the rainy season and drought in the dry season are the leading indicators of watershed damage. The phenomena of flooding and drought impact the disrupted balance of the hydrological cycle. The capacity of the river channel is smaller than the river discharge, which will cause flooding. Floods are natural hazards with a significant impact on human activities, and their frequency has been increasing during the last few years (Moe et al., 2015).

Nagan Raya District is a growing and developing district on the west-south coast of Aceh Province. Forum for environment stated that the leading cause of the flood disaster that occurred on the West Coast of Aceh was the damage to 3 watersheds, namely the Krueng Meurebo Watershed, Krueng Seunagan Watershed, and Krueng Tripa Watershed. The Krueng Seunagan watershed for upstream and downstream areas is mainly located in Nagan Raya District, where the damaged and non-forested watershed area is around 41% or 40,890 hectares. This indicates that land-use change in the Krueng Seunagan watershed has reached an alarming condition (Sari et al., 2006).

Physical conditions in the watershed can be identified by remote sensing technology. The use of high-resolution satellite imagery has replaced conventional methods for natural resource inventory and also for environmental monitoring as input for planning decision-making, especially concerning changes in watershed characteristics, both in land use and slope conditions, regarding the increased surface flow and river flow rates in various watersheds (Trisakti et al., 2008).

The characteristics of a watershed (DAS) will be influenced by several factors, including the area and shape of the watershed, topographical conditions, geological conditions, and land cover or land use (Sudarto, 2009). The availability of data related to the physical parameters of the watershed is still minimal; hence an alternative is needed to obtain data with remote sensing technology, which is a technique for providing data and geographic information quickly and accurately.

Information on the physical characteristics of the watershed towards peak discharge and river storage capacity is needed for flood control planning by taking into account the physiographic factors of the watershed. Therefore, this study aims to determine the peak discharge based on the watershed's physical characteristics by comparing the river holding capacity.

Materials and Methods

Time and Site

The research was carried out in the Krueng Seunagan watershed, where most of the area is located in Nagan Raya District, Aceh Province, and is one of the causes of flooding or inundation in the downstream area. Geographically, the Krueng Seunagan watershed is located between 04001'18,625" - 04025'47,902" North Latitude and 96011'39,934 "- 96050'23,300" East Longitude (Figure. 1). The research was conducted from February 2019 to August 2019 through field surveys, data collection, data processing (Non-Spatial Data and Spatial Data), and data analysis. The discharge data and data collection points were measured using a current meter and GPS.

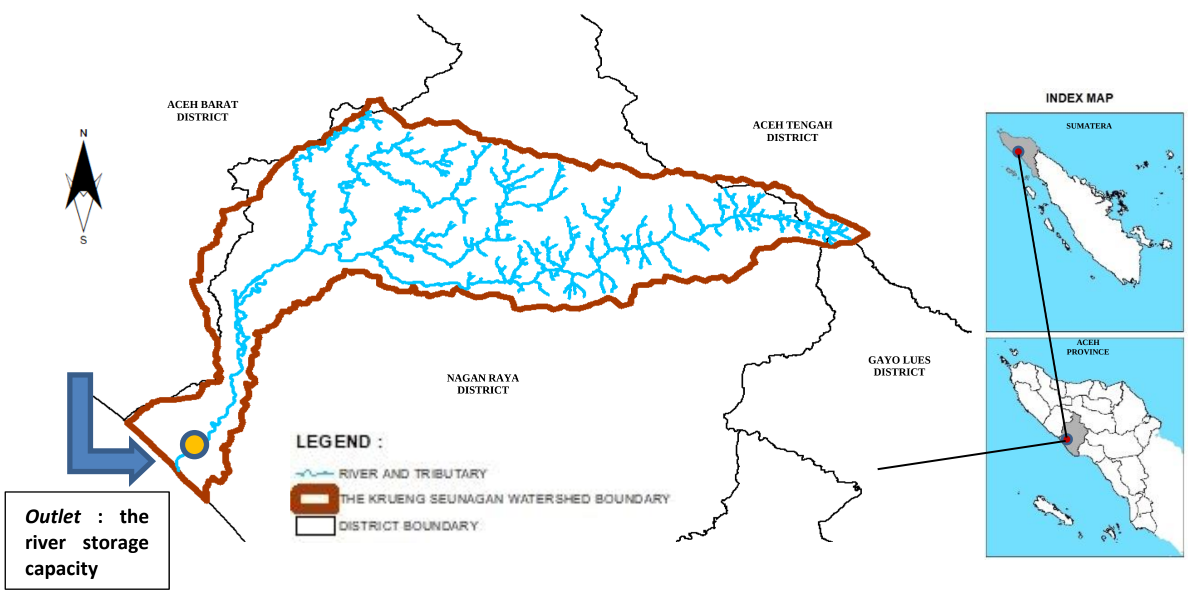
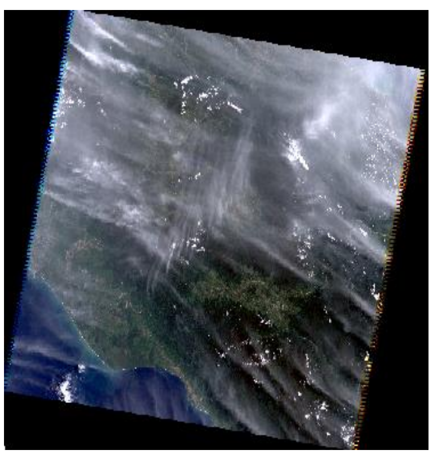


Figure 1. Map of Research location

Data Collection

One of the software used was ArcGIS 10.5 to perform spatial analysis by utilizing existing tools related to watershed characteristics and processing images. Erdas Imagine 2015 software is used for the stacking process of Landsat images and composite bands to determine land use classification and land cover. Global Mapper 13 software is automatically used to process AsterGDem satellite imagery for watersheds or watersheds. SASPlanet and Google Earth applications are used as assisting tools in giving correction or overlay in selecting high-resolution satellite imagery processes.

Shapefile (SHP) data Krueng Seunagan watershed condition (Directorate General of Forestry Planning of Ministry of Forestry and Environment of the Republic of Indonesia). Download the KML format watershed boundaries for Sumatra on the link. http://appgis.dephut.go.id/ appgis / kml.aspx. Daily rainfall data for the last 15 years (2003-2018) were obtained from the Rain Post, assisted by the Sumatra-I River Basin Agency and the Local BMKG. Rainfall data is used to determine the daily rainfall for 2003 to 2018. The 2016 SHP map provided by BIG (Geospatial Information Agency) is used as a base map for research reference (Regency Boundary, District Boundary, etc.). Soil Type Map from PDGA (Aceh Geospatial Data Center, Bappeda Aceh). In 2016, Landsat 8 OLI/TIRS (Operator Land Imager/Thermal Infrared Sensor) digital imagery was acquired on December 18, 2017, and acquired on November 5, 2013. Landsat TM digital imagery. 5 with acquisition dates on August 19, 2008, and December 28, 2003, for the path / raw: 130/57 respectively obtained from the download results on the website. www.earthexplorer.usgs.gov. Digital image of AsterGDem V.2 as of October 2011 with arcsec resolution (30 x 30 m) was obtained from the website. www.earthexplorer.usgs.gov. Which is used to obtain watershed contour and morphometric data.



321-Natural Band Composite
(Landsat TM imagery. 5) acquisition
December 28, 2003

432-Natural Band Composite
(Landsat TM imagery. 8) acquisition
December 18, 2017

Figure 2. Landsat Digital Image

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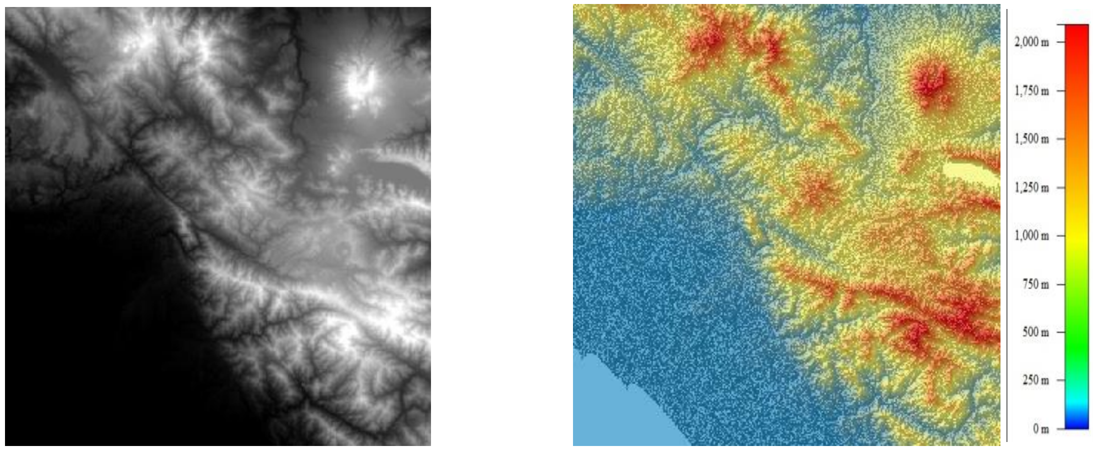

Figure 3. Digital Image of AsterGDem V.2

Based on the land use obtained, a weighted runoff coefficient (C) is acquired, calculated through the equation. 1:

$$\mathrm{C-Weighted} = \frac{(\mathrm{R\ x\ Cr}) + (\mathrm{S\ x\ Cs})}{\mathrm{A}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathrm{Equation.\ 1})$$

Where:

R = Land use area R (ha)
S = Land use area R (ha)
Cr = Runoff coefficient for land use type R
Cs = Runoff coefficient for land use type S
A = The total area of the watershed (R+S) ha

The calculation of the river storage capacity downstream is used to determine the amount of discharge (in the form of water volume) that the river can accommodate per unit of time at critical points or areas that are frequently flooded by calculating the river profile. The discharge measurement for flow velocity is not measured directly. Still, it is calculated based on the hydraulic discharge formula, namely the "formula Manning who is expressed in the form of equations 2 and 3:

$$\mathrm{V} = \frac{1}{\mathrm{n}}\ \mathrm{x}\ \left(\mathrm{R}^{\frac{2}{3}}\ \mathrm{x}\ \mathrm{S}^{\frac{1}{2}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathrm{Equation.\ 2})$$

$$\mathrm{Q} = \mathrm{A\ x\ V} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathrm{Equation.\ 3})$$

Where :

Q = Discharge (m^3/detik)
A = Wet cross-sectional area (m^2)
V = Flow rate (m / sec)
R = Hydraulic radius
P = Wet circumference
S = Mean slope
n = Manning coefficient (0,040)
L = Width of river (m)
D. =. Water level (m)

Based on the comparison between the discharge Q1 (peak discharge using the rational method of the watershed) and discharge Q2 (carrying capacity of the river), then the criteria that can be used is acquired (Chambers, 1981; Flemming, 2002) if:

- $Q_1 > Q_2$ then there will be a flood and
- $Q_1 < Q_2$, then there is no flood.

Thus, the value of Q_1 and Q_2 can be considered as a safe boundary condition between runoff discharge and river discharge. Q (discharge) calculation using the Rational Method requires rainfall intensity data, namely the depth of rainwater per unit of time or short-term rainfall in units of mm/hour (Sudarto, 2009). Rain intensity is the height of rainfall that occurs in a period where the water is concentrated is influenced by the duration of a rain event (duration) or concentration-time (tc) using the "Kirpich" formula and the maximum rainfall for 24 hours. Peak runoff discharge with rational equations 4, namely:

$Q = 0.00278 \times C \times I \times A$ ………………………………………………………………….... (Equation. 4)

Where:
Q = Surface runoff peak discharge (m^3/sec)
C = Flow rate (dimensionless)
A = Watershed area (km^2)
I = Rainfall intensity (mm / hour)

Result

Watershed Morphology

Soil type influences the size of surface water flow, whether large or small. Based on the soil type map in the research area (Krueng Seunagan watershed), the USDA includes 4 (four) types of soil, namely (1). Inceptisol (22.7%), (2). Ultisol (72.64%), (3). Entisol-Inceptisol (1.69%), and (4). Histosol (2.97%).

The elevation (elevation) in the Krueng Seunagan watershed based on analysis using the map of AsterGDEM with ArcGIS shows that at an elevation of 0-500 masl, it dominates an area of 43,712.58 ha (44.12%) and is followed successively by elevation >2000 masl covering 25,945.75 Ha (26.19%), 1500-2000 masl covering 16,638.63 masl (16.79%), 1000-1500 masl covering 7,156.76 Ha (7.22%) and 500-1000 masl covering an area of 5,623.26 Ha (5.68%).

The slope of the Krueng Seunagan watershed was carried out using the AsterGDEM image in raster format, which presented the elevation of the place and automatically calculated the difference in elevation adjacent to the horizontal (horizontal) and vertical (vertical) directions as a percentage (%). The results of the slope mapping show that the Krueng Seunagan watershed is dominated by a slope of flat/gentle slopes (0-8%) covering an area of 21.769,42 Ha (21.97%). It is respectively followed by steep slopes (25-45%) covering an area of 28,438.85 Ha (28.70%), steep slopes (>45%) covering an area of 17.956,25 Ha (18.12%), and then followed by slightly sloping slopes (8-15%) covering an area of 16,113.48 (16.26%) and sloping slopes (15-25%) covering an area of 14,798.98 Ha (14.94%).

The Watershed Morphometric

The shape of a watershed will affect the peak flow rate, where the watershed area will affect the speed and volume of surface flow. The broader a watershed, the greater the surface flow volume, while the shape of a watershed affects the flow pattern in the river. The watershed shape is difficult to express quantitatively, but the circularity ratio can approximate it. Where it is known that the area of the Krueng Seunagan watershed is 990.76 km2, and the circumference of the watershed is 111.53 km, so the results of the calculation of the form factor of the watershed (Rc) obtained a value of 1.0004 (Rc> 0.5). The index number (Table. 1) shows the number of tributaries or channels in a watershed. In this river density figure, the channel density describes the average length of the river in a specific area.

Table 1. River Branch Rate Index in the Krueng Seunagan Watershed

River Orde	Total river flow length (Km)	Average River Length	Total orde of the river (Nu)	(Nu+1)	Rb = (Nu/Nu+1)	Index Rb	WRb
Orde. 1	192.15	1.05	182	68	2.67		
Orde. 2	91.31	1.34	68	12	5.66		
Orde. 3	65.89	5.49	12	4	3	3.07	20.21
Orde. 4	12.,24	31.81	4	1	4		
Orde. 5	44.35	44.35	1	0	0		
Total	**520.94**	**1.95**	**267**	**85**	**15.33**		

Source: Calculation and Data Analysis Results (2019)

The river density (Dd) in the Krueng Seunagan watershed is 0,53, including the density class. "Moderate" is considered where the river flows through rocks with softer resistance (resistance) so that the sediment transport carried by the flow will be greater. While the Branching Rate Index (Rb. 3-5) is worth 20.21 and it is stated that the river channel has an increase and decrease in the flood water level, which is neither too fast nor too slow.

The main river slope is the ratio of the difference in the height of the longitudinal cross-section of the river between the upstream and the downstream with the horizontal length of the main river/main river. How to determine the average river slope can be seen in the illustration of the longitudinal cross-section of the main river and the measurement of the slope of the straight line that is drawn starting from the outlet, as shown in Figure 4.

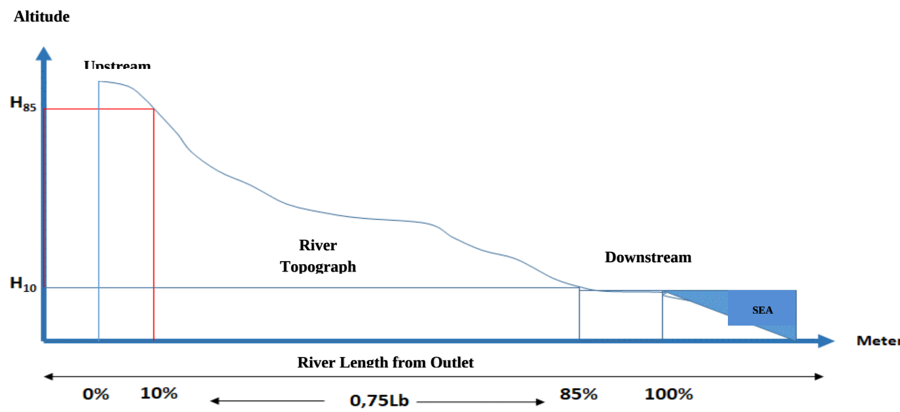

Figure 4. Illustration of main river length percentage (Lb) in projection flat on the Krueng Seunagan watershed

Morphometric parameters (Table 2) with an area of the Krueng Seunagan watershed covering an area of 990.76 Km² and circumference of the watershed 111.53 Km, thus the calculation of the form factor of the watershed (Rc) obtained a value of 1.0004 (Rc> 0.5). The shape of an area flow will affect the peak flow rate. The area of a watershed will affect the speed and volume of surface flow; the wider a watershed, the greater the surface flow volume, while the shape of a watershed affects the flow pattern in the river. Characteristics of the watershed shape are presented on the Krueng Seunagan Watershed Map. It can be inferred that the watershed has a radial shape where the drainage area can be seen in the form of a fan or circle and is wide, with tributaries concentrating to a point radially. This drainage area tends to result in a more significant flood discharge occurring at the meeting point of the tributaries. The shape of this watershed affects the flow pattern in the river; when viewed, the Krueng Seunagan watershed has a wide or circular form of the watershed so that the concentration-time is faster at the control point resulting in the rate and volume of surface runoff.

Table 2. Morphometric parameters of The Krueng Seunagan watershed

Morphometric Parameters	Morphometric Value	Unit	Formula
Watershed area	990.76	Km²	A = Lb x W
Longest river	105.20	Km	= Lb
Main River Length	8.90	Km	= 0.75 x Lb
Watershed width	9.42	Km	W = A / Lb
Tour the watershed	111.53	Km	$A = \pi r^2$ P = $2\pi r$
River slope (Su)	1.16	%	$\mathrm{Su} = \frac{(h_{85} - h_{10})}{0.75\ \mathrm{Lb}}$
Round Ratio (Rc)	1.0004	Rc > 0.5	$\mathrm{Rc} = \frac{4\pi.\mathrm{A}}{\mathrm{P}^2}$
River Density Rate (Dd)	0.53	Km/Km²	Dd = Ln/A
River Branch Rate (Wrb)	20.21		$\mathrm{WRb} = \frac{\sum \mathrm{Rb}_{\frac{u}{u}+1}(\mathrm{N_u} + \mathrm{N_{u+1}})}{\mathrm{N_u}}$

Source: Calculation and Data Analysis Results (2019)

Land-use changes in the Krueng Seunagan watershed are varied. This is shown in Table 3. The average forest area decreased by 1.72% from 2003-2017. In 2008, the forest area decreased by 1.721% from 2003. In 2013, the forest area decreased by 0.36% from 2008 and declined by 3.6% in 2017 from 2013.

The residential area in the Krueng Seunagan watershed has continued to increase every year of observation from 2003-2017. This is certainly in line with the city's development and the increase in population in the districts and villages in the Krueng Seunagan watershed. The increase in land use for settlements was 0.56% in 2013 in the 2008-2013 changes and 1.79% in 2013-2017. Increase in residential land area from 2003-2017 covering an area of 3,144.25 Ha from an area of 749.31 Ha in 2003.

Table 3. Changes in the land-use area in The Krueng Seunagan watershed for the period of 2003-2008, 2008-2013, and 2013-2017

Land Use	Period of Land Use Change					
	2003-2008		2008-2013		2013-2017	
	Area (Ha)	(%)	Area (Ha)	(%)	Area (Ha)	(%)
Forest	- 1,202.32	- 1.21	- 356.40	- 0.36	- 3,564.37	- 3.60
Mixed Garden	- 362.41	- 0.37	- 271.89	- 0.27	208.56	0.21
Settlement	812.72	0.82	554.81	0.56	1,776.72	1.79
Plantation	315.27	0.32	576.09	0.58	-	-
Dryland Farming	- 652.08	- 0.66	- 1.992.77	- 2.01	1,520.09	1.53
Rice Fields	472.97	0.48	- 275.38	- 0.28	- 387.75	- 0.39
Body of Water	293.95	0.30	511.84	0.52	139.10	0.14
Shrubs	321.90	0.32	1.253.70	1.27	307.65	0.31
Total	**0.00**	**0.00**	**- 0.00**	**- 0.00**	**0.00**	**0.00**

Source: Calculation and Data Analysis Results (2019)

Note: Results of Landsat Digital Image Interpretation, a Negative Sign (-) indicates a reduction in land area, a Positive Sign (+) indicates an increase in land area.

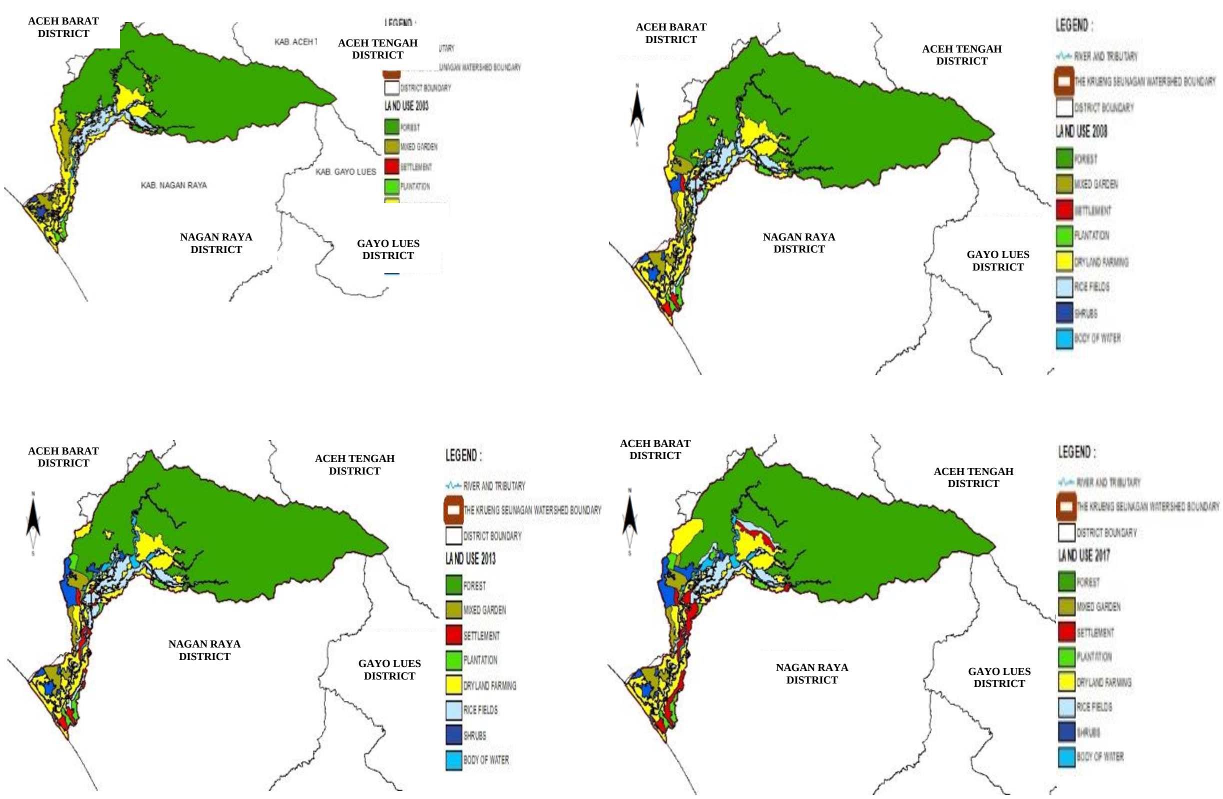

Figure 5. Existing land use from period 2003 – 2017

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Land use that is unsuitable for unsustainable development and planning will affect the environment and people. There are 6 (six) aspects of the influence of forests on hydrology, namely (a) forests increase rainfall, (b) forests increase river flow and forest vegetation can reduce surface water runoff, (c) forests regulate river flow fluctuations, (4) forests can reduce erosion, (5) forests reduce flooding and (6) forests can improve water supply quality. Land-use change can be mapped as shown in Figure 5.

Watershed Meteorology

The maximum daily rainfall data is sourced from 4 rainfall posts close to the Krueng Seunagan watershed, namely Sawang Teubee Rainfall Post, Kampung Mesjid Rainfall Post, Jeuram Dam Rainfall Post, Mount Kong Rainfall Post, with recording periods from 2008-2018. (10 years) without data for 2010. The following is the availability of maximum daily rainfall data (mm/day) for each rain post, as presented in Table 4. This maximum daily rainfall data is obtained from the largest daily rainfall at four rainfall posts in one year.

To determine the average rainfall in a watershed, the analysis of maximum rainfall data obtained from 4 rain posts is conducted using the analysis "Thiessen Polygon Method" (Figure 6). Calculation of the rain station post area and the acquisition of the Thiessen coefficient in the Krueng Seunagan watershed is shown in Table 5.

Rainfall intensity is calculated using the mononobe formula by entering one of the concentration-time variables in addition to the maximum rainfall variable that occurs. Time of concentration (Tc) is the travel time required by water from the farthest place (upstream of the watershed) to the point of observation of water flow (*outlet*). This occurs when the land along these two points is saturated, and all other earth basins have been filled with rainwater. It is assumed that if the duration of rain is equal to Tc, it means that all parts of the watershed have contributed to the flow of water (discharge) that reaches the point of observation (Subarkah, 1987, Vissman, 1977, in Suripin 2004).

The concentration-time value (Tc) obtained in the Krueng Seunagan watershed is 3,9907 hours, where the maximum length of the flow is 105.2 km, and the slope of the river in the Krueng Seunagan watershed is 0,011. From these data, the value of Rainfall Intensity, where the intensity of rainfall in 2003, due to not getting rainfall data, is assumed to be the same as in 2008. Maximum rainfall and rainfall intensity in the period of the observation year can be seen in Table 6. Based on the return period, rainfall and rainfall intensity rain can be seen in Table 7.

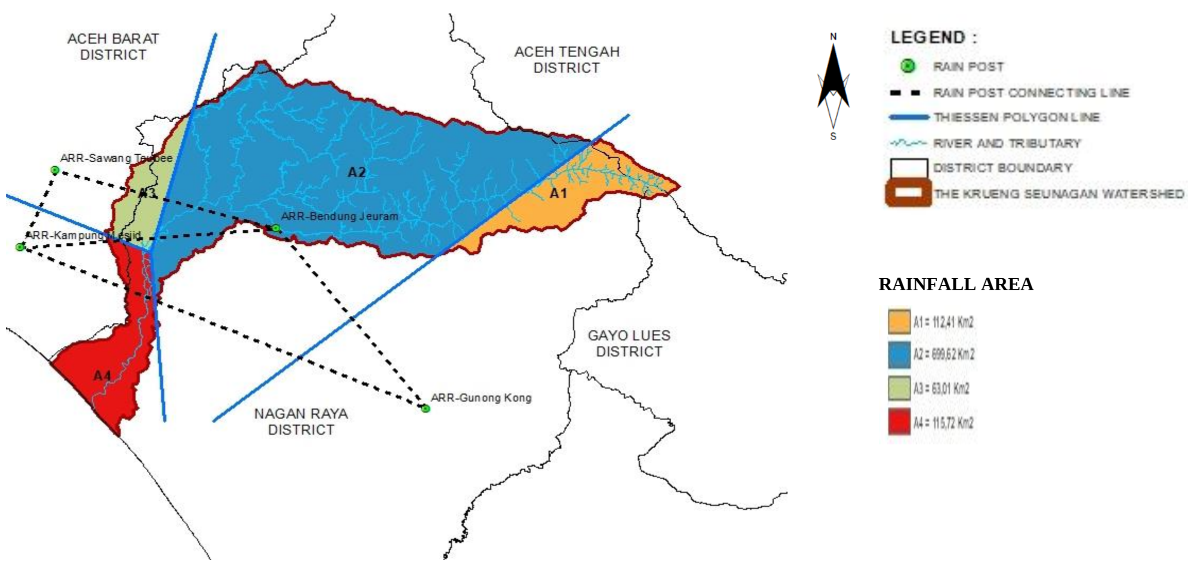

Figure 6. Area of rain post using Thiessen polygon method

Table 4. Rainfall data from 4 rain posts for the ten years (2008-2018)

Year	Maximum daily rainfall (mm)			
	Jeuram Weir	Kampung Mesjid	Sawang Teubee	Gunung Kong
2008	0.0	127.0	0.0	0.0
2009	0.0	175.0	0.0	0.0
2010	0.0	0.0	0.0	0.0
2011	0.0	125.0	0.0	0.0
2012	0.0	92.0	0.0	0.0
2013	7.,0	190.0	105.0	95.2
2014	77.0	235.0	110.8	180.9
2015	77.7	215.0	160.0	127.8
2016	306.1	215.0	143.5	164.4
2017	116.0	215.0	132.0	133.2
2018	116.0	215.0	130.0	141.7
Total	**762.8**	**1804.0**	**781.3**	**843.2**
Mean	**127.1**	**180.4**	**130.2**	**140.5**

Source: Calculation and Data Analysis Results (2019)

Table 5. Rain post area and Thiessen coefficient in the Krueng Seunagan watershed

Year	Jeuram Weir	Kampung Mesjid	Sawang Teubee	Gunung Kong	$\bar{R}$
	A = Area of Rain Effect				
	A1 = 699.62 km^2	A2 = 115.72 km^2	A3 = 63.01 km^2	A4 = 112.41 km^2	
2008	89.5	127	91.7	98.9	95.09
2009	123.3	175	126.3	136.3	131.03
2011	88.1	125	90.2	97.4	93.59
2012	64.8	92	66.4	71.7	68.88
2013	70	190	105	95.2	89.1
2014	77	235	110.8	180.9	109.39
2015	77.7	215	160	127.8	104.66
2016	306.1	215	143.5	164.4	269.04
2017	116	215	132	133.2	130.53
2018	116	215	130	141.7	131.37

Source: Calculation and Data Analysis Results (2019)

Table 6. Maximum rainfall and rainfall intensity in the observation year period

Year	Rmak (mm)	Tc (hour)	I (rainfall intensity) mm /hour
2003	95.09	3.99	13.11
2008	95.09	3.99	13.11
2013	89.10	3.99	12.28
2017	130.52	3.99	17.96

Source: Calculation and Data Analysis Results (2019)

Analysis of Peak Discharge and River Storage Capacity

The runoff coefficient represents the effect of a watershed on rainwater loss into surface runoff, where the runoff coefficient rate itself depends on natural conditions and soil surface, including slope, soil moisture, infiltration, and rain intensity (Eripin, 2005). The more impermeable a soil surface is the higher the flow coefficient value.

The coefficient is defined as the maximum velocity of water flow from the catchment area. If the amount of rainfall that falls on the surface exceeds the amount of water needed, surface runoff can occur. If the rain that occurs is small, then almost all of the rainfall that falls is intercepted by dense vegetation (Kodoatie and Sjarief, 2008). The effect of land use on surface runoff is expressed in runoff coefficient (C), a number that displays the ratio between runoff and rainfall. The runoff coefficient figure is an indicator to determine the physical condition. C values range from 0-1. The value of C = 0 indicates that all rainwater is intercepted and infiltrated into the soil; on the other hand, C = 1 indicates that rainwater flows as surface runoff (Kodoatie and Sjarief, 2008).

The runoff coefficient (C) of land use in the Krueng Seunagan watershed can be seen in Table 8 from 2003-2017 (with five-year interval observations). The C value from year to year increased by 12.40% in 2008 and 20.15% in 2013 and increased by 42.51% in 2017 compared to the runoff coefficient value in 2003. The C value obtained was around 0.05048 in 2003. Some of the rainfall that falls in the Seunagan Watershed is infiltrated, and some is also a runoff.

The more impermeable the soil surface is, the higher the runoff coefficient value obtained. This is because water is not capable of seeping into the soil. Changes from land to developed land have the potential to increase surface runoff; inbuilt land, the soil surface is more covered and hardened, so the infiltration area is getting smaller. Whereas in open land, there is no cover which is helpful in water absorption.

In the watershed, which is classified as good, the value of C is close to 0, and in damaged watershed conditions, the value of C is getting closer to 1. Classification of the importance of C is if C <0.25 is classified as good or not dangerous, 0.25-0.50 is moderate, and 0.51 – 1.0 is classified as bad (Koodatie and Syarief, 2005). In the Krueng Seunagan watershed area, the C value obtained was 0.05048 – 0.07195, indicating that the Krueng Seunagan watershed area was classified as good or harmless. The increase in the value of C from 0.05048 in 2003 to 0.07195 in 2017 was very small. The weighted C value of more than 0.5 can be categorized as the watershed has experienced degradation.

Table 7. Rainfall and Rainfall Intensity Rain Based on the Return Period

Return Period	Rmak (mm)	I (rainfall intensity) mm/hour
2	105.50	14.54
5	147.92	20.38
10	185.89	25.61
25	247.24	34.07
50	304.55	41.96
100	373.09	51.41

Source: Calculation and data analysis results (2019)

Table 8. Runoff Coefficient Values in Year Observations Based on The Land Use

Land Use	Coefficient	2003		2008		2013		2017	
		Area (Ha)	C-Weighted	Area (Ha)	C-Weighted	Area (Ha)	C-Weighted	Area (Ha)	C-Weighted
Forest	0.02	73,541.28	1,470.83	72,338.96	1,446.78	71,982.56	1,439.65	68,418.19	1,368.36
Mixed Garden	0.10	3,581.28	358.13	3,218.87	321.89	2,946.98	294.70	3,155.54	315.55
Settlement	0.60	749.31	449.59	1,562.03	937.22	2,116.84	1,270.10	3,893.56	2,336.14
Plantation	0.40	667.56	267.02	982.83	393.13	1,558.92	623.57	1,558.92	623.57
Dryland Farming	0.10	13,281.60	1,328.16	12,629.52	1,262.95	10,636.75	1,063.68	12,156.84	1,215.68
Rice Fields	0.20	5,012.74	1,002.55	5,485.71	1,097.14	5,210.33	1,042.07	4,822.58	964.52
Body of Water	0.05	1,553.63	77.68	1,847.58	92.38	2,359.42	117.97	2,498.52	124.93
Shrubs	0.07	689.58	48.27	1,011.48	70.80	2,265.18	158.56	2,572.83	180.10
Total		**99,076.98**	**5,002.22**	**99,076.98**	**5,622.29**	**99,076.98**	**6,010.30**	**99,076.98**	**7,128.85**
C-mean		**0.050488254**		**0.056746711**		**0.060662889**		**0.071952596**	

Source: Calculation and data analysis results (2019)

River Storage Capacity (Q_2)

The principle of measuring or calculating the river's holding capacity is to measure the wet cross-sectional area, flow velocity, and depth (Syakuri, 2013). Instantaneous discharge measurements in the field were carried out on April 11, 2019, in the downstream Krueng Seunagan watershed with coordinates 193.835 east longitude and 450.165 longitudes. The cross-section measurement is based on the characteristics of the river by using the formula manning worth 159.88 m3/sec (Table 9). Debit obtained from measurements in the field by using the current meter at a point downstream of the Krueng Seunagan worth 157.07 m3/sec (Table 10). This debit is not much different from a current meter's biophysical measurement results. According to the cross rivers result, it is inferred that the discharge that can be accommodated by the downstream river Krueng Seunangan is the average value of the measurement is 158.47 m3/sec.

Table 9. River discharge based on the downstream river section of the Krueng Seunagan watershed

SEG	V = 1/n ($R^{2/3}$ x $S^{1/2}$)					A = L*D			P = L + 2D			R = A/P			S = H/(0.9*L)			Q = V*A
	V	n	1/n	$R^{2/3}$	$S^{1/2}$	A	L	D	P	L	2D	R	A	P	S (Slope)	H (8-2) masl	L (m)	(m^3/s)
I	0.38	0.04	25	2.98	0.005	74.33	10	7.43	24.87	10	14.87	2.99	74.33	24.87	0,01	6	650	28.39
II	0.39	0.04	25	3.05	0.005	76.67	10	7.67	25.33	10	15.33	3.03	76.67	25.33	0,01	6	650	30.01
III	0.39	0.04	25	3.01	0.005	75.33	10	7.53	25.07	10	15.07	3.01	75.33	25.07	0,01	6	650	29.08
IV	0.34	0.04	25	2.65	0.005	64.67	10	6.47	22.93	10	12.93	2.82	64.67	22.93	0,01	6	650	21.97
V	0.32	0.04	25	2.45	0.005	59.33	10	5.93	21.87	10	11.87	2.71	59.33	21.87	0,01	6	650	18.67
VI	0.29	0.04	25	2.25	0.005	54.00	10	5.40	20.80	10	10.80	2.60	54.00	20.80	0,01	6	650	15.55
VII	0.22	0.04	25	1.74	0.005	42.00	10	4.20	18.40	10	8.40	2.28	42.00	18.40	0,01	6	650	9.35
VIII	0.14	0.04	25	1.09	0.005	28.33	10	2.83	15.67	10	5.67	1.81	28.33	15.67	0,01	6	650	3.96
IX	0.09	0.04	25	0.70	0.005	20.33	10	2.03	14.07	10	4.07	1.45	20.33	14.07	0,01	6	650	1.82
X	0.07	0.04	25	0.51	0.005	16.50	10	1.65	13.30	10	3.30	1.24	16.50	13.30	0,01	6	650	1.09
															Total river discharge			159.88

Source: Calculation and Data Analysis Results (2019)

Table 10. River discharge in the downstream of the Krueng Seunagan watershed using current meter

River Length	River Width	In The River	In The Wheel	Flow Speed (V)	Average Speed (V)	A = D*L	Q = V*A
(m)	**(m)**	**(m)**	**(m)**	**(m/dt)**	**(m/dt)**	**(m^2)**	**(m^3/s)**
10	10	7.43	0.25 0.75	0.2 0.3	0.25	74.33	18.58
20	10	7.67	0.25 0.75	0.3 0.2	0.25	76.67	19.17
30	10	7.53	0.25 0.75	0.4 0.4	0.40	75.33	30.13
40	10	6.47	0.25 0.75	0.4 0.3	0.35	64.67	22.63
50	10	5.93	0.25 0.75	0.4 0.5	0.45	59.33	26.70
60	10	5.4	0.25 0.75	0.4 0.2	0.30	54.00	16.20
70	10	4.2	0.25 0.75	0.4 0.3	0.35	42.00	14.70
80	10	2.83	0.25 0.75	0.2 0.1	0.15	28.33	4.25
90	10	2.03	0.25 0.75	0.2 0.1	0.15	20.33	3.05
100	10	1.65	0.25 0.75	0.1 0.1	0.10	16.50	1.65
Total River Discharge							**157.07**

Source: Calculation and Data Analysis Results (2019)

The peak discharge estimation considers the surface flow coefficient, rainfall intensity, and river basin area (Sudaryatno, 2006). There is a very close relationship between surface runoff, land cover, and topography. Peak discharge obtained using the rational formula in 2003 amounted to 183.52 m^3/sec, the peak discharge of 2008 acquired amounted to 220.50 m^3/sec, in 2013 obtained the discharge of 206.62 m^3/sec, and in 2017 obtained the discharge of 358.44 m^3/sec. Increasingly with years, the debit obtained is also increasing. In 2013, the discharge was somewhat reduced because it was influenced by a low maximum rainfall value so that a smaller rainfall intensity was obtained. The increase in discharge was 95.32% during the observation time based on land use, with an increase in the runoff coefficient of 42.51%. While the rise in maximum rain intensity varies, the magnitude of the increase in rain intensity is 37.05% (Table 11).

A flood is a river that flows beyond the capacity of the river, and the river flows through the river bank and overflows to the left and right of the river, inundating the surrounding area that consequently can cause economic loss or even cause loss of life (Sudarto, 2009, Gleick et al. 2013). Flood event analysis is determined based on the probability of the occurrence of flood discharge and by utilizing flow hydrograph characteristics, for example, a return period of a peak discharge (Asdak, 1995). Land use activities that change the type or type of land cover in a watershed can often increase and decrease water yield (Asdak, 1995). The causes of flooding include low river capacity, water catchment areas, weather conditions before the rain event, land cover, and topography (Osei et al., 2021). As a watershed ecosystem, changes upstream will affect other parts of the watershed. Upstream changes are closely related to flooding, where the soil cannot absorb rainfall due to reduced water catchment areas (Ali et al., 2015).

Widyaningsih (2008) explains that the effect of land use on the hydrological aspects of a watershed is closely related to the function of vegetation as land cover, which can increase infiltration capacity and retain surface runoff and increase surface storage so that it will reduce the amount of surface flow which in turn reduces the amount of inflow to the river. Azmeri et al. (2020) researched the Krueng Baro watershed found the regions experiencing severe and very severe soil loss were closely correlated with steep gradients and deforestation.

Table 11. The peak discharge in Krueng Seunagan using rational method

Year	**Runoff coefficient**	**Rainfall intensity (mm/hour)**	**Discharge (m^3/sec)**
2003	0.0505	13.1027	183.52
2008	0.0567	13.1027	220.50
2013	0.0607	12.2776	206.62
2017	0.0720	17.9573	358.44

Source: Calculation and Data Analysis Results (2019).

Based on the comparison between the Q1 discharge (the peak discharge of the watershed using the rational method) and the Q2 discharge (river carrying capacity), the criteria can be used is that if Q1 > Q2, then there will be "flooding" and/or Q1 < Q2 then "There was no flood." Flood will happen in the area of Krueng Seunagan watershed when the flood peak discharge rational method is larger than the capacity of the river to measure the discharge of 158.47 m3/sec.

However, if calculated based on the annual rainfall average of 4 stations measuring rainfall intensity, the average rainfall values obtained are 1.35 mm/hour in 2013 and 3.51 mm/hour in 2017. The discharge values obtained are 22.30 m3/sec (2013) and amounting to 68.65 m3/sec (2017). This means that it is still in a normal area and the river flow rate in Krueng Seunagan is still below the river's capacity.

Calculation methods by Hasper, Melchior, Synthesis Unit hydrograph (HSS) and HSS Nakayasu Snyder (Alfiansyah, 2019) yielded the peak discharge period of 5 years each at 356.49 m^3/sec (Method Hasper); 869.90 m^3/sec (Method Melchior); 518.56 m^3/sec (HSS Snyder) and 1,374.14 m^3/sec (HSS Nakayasu). The peak discharge obtained is greater than the river holding capacity. Thus, flooding is the main problem of the Krueng Seunagan River, where almost every year the overflow of the Krueng Seunagan River causes economic losses to the community. Management of water resources by the government shows less than optimal results. Azwar (2015) has conducted a study of the planned flood discharge at Krueng Seunagan using the HSS Gama I method. The study results show that the complex characteristics of the watershed have contributed a great potential to flooding caused by Krueng Seunagan. The shape of the Krueng Seunagan watershed, round/widened and circular with a short concentration-time, can cause high flood fluctuations.

Conclusions

The river flow density of 0.53 belongs to the "medium" category. The value of the form factor of the Seunagan watershed of 1.0004 shows that a broad basin with a short concentration time can cause high flood fluctuations. Land use in the Krueng Seunagan watershed increases peak discharge during the observation year (2003-2017). Apart from land-use factors, discharge is also influenced by high rainfall intensity and runoff coefficient obtained from land use analysis. The runoff coefficient in the Krueng Seunagan watershed increased by 42.51%, and rainfall intensity increased by 37.05%, while the discharge increased by 95.31%. The discharge capacity that the Krueng Seunagan River Basin can accommodate from the measurement results in the downstream watershed is 158.47 m^3/s. While the peak discharge using the rational method gets a value that varies in each year of observation from (2003-2017). Peak discharge value in 2003 amounted to 183.52 m^3/s, and the highest in 2017 amounted to 358.44 m^3/s. This shows that the river holding capacity in the Krueng Seunagan watershed will not accept the amount of peak discharge that occurs; hence floods will always occur.

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